

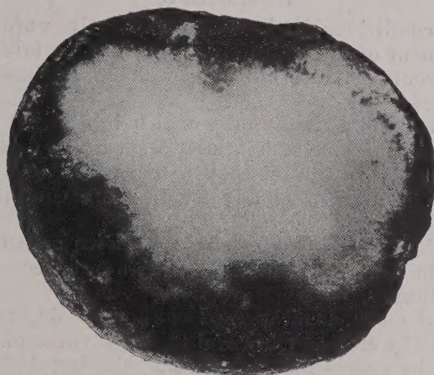
FLORA W. PATTERSON

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LATE POTATO BLIGHT IN IOWA

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AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

HORTICULTURAL SECTION

Truck Crops

AMES, IOWA

SUMMARY

Climatic conditions in Iowa are generally unfavorable to the development of the potato disease known as late blight. It is of rare occurrence here but in occasional seasons it causes serious losses.

The climatic conditions under which late blight occurs in Iowa are a high degree of humidity with heavy dews and mid-summer temperatures lower than usual. An excess of rainfall and a predominance of cloudy weather are contributing factors.

The practice of shipping in northern grown potatoes for seed is common in Iowa. Such seed is apt to be infected with the late blight fungus.

The use of clean, healthy seed cannot be depended on to insure a healthy crop of vines and tubers because of the danger of infection by spores blown from neighboring diseased fields.

Small, shrunken dark spots and a brownish discoloration just under the skin of the potato are indications of the preliminary stages of dry rot. Any tubers so affected should not be planted. They give a low percentage of germination and, when the season is favorable, infect the crop with late blight.

Blight infected potatoes under moderate temperatures, as in warm cellars, show a high percentage of loss from rotting.

Potatoes may be held cool by leaving them in the ground as late as possible, or by putting them in cold storage.

When held at 38° Fahrenheit, the loss in storage of potatoes infected with late blight is but slight; above 40° the disease develops rapidly, and below 38° the tubers lose flavor by becoming "sweetish" which, however, can be corrected by holding temporarily at a higher temperature.

Early digging of a blight infected crop is advisable only when the potatoes can be profitably marketed at once.

Early planting and the use of the bordeaux spray are two of the most effective methods of preventing loss from late blight in Iowa.

LATE POTATO BLIGHT IN IOWA

By A. T. Erwin.

At least three pronounced outbreaks of the late blight of the potato, *Phytophthora infestans*, have occurred in Iowa within the past 45 years. These were in 1885*, 1903**, and 1915**.

This disease is more or less common throught the cooler regions of the north from which Iowa receives its seed supply and is therefore probably introduced into some portions of the state every year. The fact that under normal climatic conditions it does not survive even when so introduced, and yet in occasional years break forth in a virulent form, presents an interesting problem.

In parts of the New England states late blight is usually present, but fails to develop only in dry years. In Iowa the conditions are reversed. It is usually absent and its presence in every known instance has been accompanied by abnormal conditions of wet weather and low midsummer temperatures. This indicates an interrelationship between these outbreaks and atmospheric conditions, and a study of that relationship is presented in the following pages.

The relationship between many diseases and certain climatic factors is well known. It is usually difficult, however, to determine which factors are operative and which nonoperative. The fact that in Iowa the outbreaks of this potato blight have always been accompanied by abnormal conditions permits of a careful study of its relation to those conditions and hence presents an approach to the problem from a direction the reverse of that in the New England states, where considerable attention has been given to this disease.

Notable studies of late blight have been made under laboratory conditions, the most recent being those of Melhus 3. These have contributed important information relative to the life history of the fungus and cleared away a number of erroneous conclusions based upon its supposed similarity to other mildews whose life histories were well known. But laboratory studies, however important, require confirmation under field conditions covering long periods of time and in different sections of the country.

* The outbreak for 1885 was reported by Halsted ¹ and those for 1903 and 1915 came under the observations of the writer ¹ Halsted, B. D., Bot. Dept. Bull. Ia. Agrl. College 95. Feb. 1888.

** Specimens from the two last named outbreaks are on file in the Botanical dept. herbarium of this institution and are identified by L. H. Pammel. Pammel, L. H. Fungus Diseases in Iowa. Ia. Ac. Sc. 1:60-1909.

3 Melhus, I. E., Jour. Agrl. Res. 2. Oct. 1915.

FIELD OBSERVATIONS IN IOWA

These field data for Iowa conditions are supplied in the following pages.

It is particularly interesting to note the close agreement between the actual conditions of the field and the findings of the laboratory, a fact which emphasizes the value of laboratory investigations for the correct interpretation of field data.

This fungus of the later potato blight belongs to an important group known as the "down mildews". An infected tuber will be found to contain small thread-like growths known as the mycelium. The disease carries over winter in this mycelium stage in the tuber only. After the seed piece is planted, whenever favorable conditions of temperature and moisture prevail, this mycelium begins to grow. It follows up the sprout, develops through the stem and finally reaches the foliage, where it forms a mildew spot which bears its fruit, the so-called summer spores. This stage of its life history is known as the period of incubation, or period of primary infection.

When the conditions are right, particularly as regards moisture and temperature, these spores quickly germinate upon the leaves of the adjoining plants. Under ideal weather conditions they are rapidly produced in untold millions. The disease is extremely infectious in character and from a single infected hill an entire field may become diseased in a few days. The period of primary infection requires about three weeks; hence if the climatic conditions under which incubation is taking place, can be definitely determined, it is possible to forecast in a measure the approach of these outbreaks and thus enable the grower to arm against its attacks.

MOISTURE SUPPLY

One of the vital factors affecting the growth of diseases is moisture supply. When moisture is excessive, the plant growth is apt to be very succulent and sappy, thus affording ideal feeding grounds for the parasite and these conditions also encourage spore production.

The rainfall by months for the years of 1885, 1903, and 1915, the years of the blight outbreaks, is presented in the following table:

RAINFALL FOR IOWA IN THE YEARS OF THE BLIGHT OUTBREAK

	June	July	August	Total Departure from normal	Total percentage excess
Normal	4.38 in.	3.96 in.	3.68 in.		
1885*	5.03 in.	6.55 in.	5.10 in.	+5.25 in.	+43.03%
1903	2.86 in.	4.83 in.	6.64 in.	+2.31 in.	+19.22%
1915	4.16 in.	8.32 in.	2.81 in.	+3.27 in.	+27.20%

* For Des Moines station only.

It will be noted that the rainfall was deficient for June in two of these years. July and August were very wet for 1885, the total excess for the three months being 43 per cent. July and August of 1903 were also wet, the total excess amounting to 19 per cent. July of 1915 was very wet; with one exception it was the wettest July in the climatological history of the state. August of 1915 was dry, but the total excess of rainfall for the three months was approximately 27 per cent.

Since there is a vital relationship between weather conditions and the disease in the period of incubation, and since that period also bears a direct relationship to the time of final outbreak, or secondary period of infection, the rainfall is given in the following ten-day periods which will be called "decades":

RAINFALL FOR SUMMER MONTHS OF 1903 BY DECADES IN INCHES.
(DES MOINES STATION)

	Actual	Normal	Departure
June:			
First decade	.59 in.	1.67 in.	—1.08 in.
Second decade	1.56 in.	1.72 in.	— .16 in.
Third decade	.91 in.	1.57 in.	— .66 in.
July:			
First decade	1.57 in.	1.24 in.	+ .33 in.
Second decade	0.32 in.	1.31 in.	— .99 in.
Third decade	1.73 in.	1.31 in.	+ .42 in.
August:			
First decade	2.63 in.	1.00 in.	+1.63 in.
Second decade	.23 in.	1.48 in.	—1.25 in.
Third decade	3.86 in.	1.13 in.	+2.73 in.
Total	13.40 in.	12.43 in.	+ .97 in.

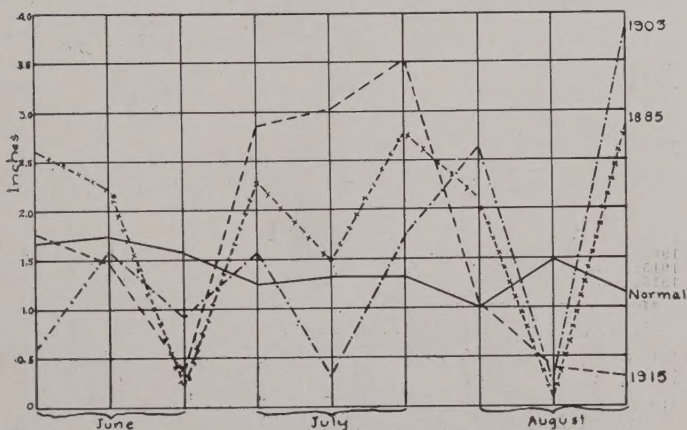


Fig. 1. Rainfall by decades of each month at the Des Moines station.

In two instances the first decade of June was wet, and in one, dry. The second decade of June in two of the years was dry, and wet in one. The third decade of all three Junes was dry. These conditions point to the fact that an excess of moisture in June is not a requisite factor for the development of this disease, and that even a normal June moisture supply is not necessary. The moisture supply for June, therefore, does not seem to be a limiting factor for the development of late blight under Iowa conditions.

July was wet for all three decades of the three years, with one exception. The third decade of July was in all instances very wet the excess in two of them was quite pronounced. The conditions in this third decade of July are without doubt significant in relation to the outbreaks which occurred during this period in at least two of the epidemics. The decade in which the outbreak of 1885 occurred was not recorded, but judging from analogous climatic conditions, it also occurred probably during the third decade of July and early in August.

The first decade of August was wet in all three years. This period was also covered in at least two of these outbreaks by a period of secondary infection. The second decade of August was dry in all three instances. Since the vines were dead by this time, the atmospheric conditions for the second and third decade of August would not be significant in relation to foliage destruction.

HUMIDITY.

Humidity and rainfall are usually closely associated, though not necessarily. From the standpoint of the host plant, rainfall is probably the more important factor while humidity bears a direct relationship to the growth and development of foliage diseases. A liberal supply of atmospheric vapor and dew combined with the right degree of temperature provides ideal conditions for spore production and germination. In the following table is presented the humidity data for the three years in question.

HUMIDITY FOR IOWA IN THE YEARS OF POTATO BLIGHT OUTBREAK

Normal	June	July	August	Total Percentage Departure from Normal
1885*....	68.0%	67.6%	71.4%	
1903.....	76.6%	79.8%	79.7%	+29.1%
1915.....	71.1%	72.2%	78%	+14.3%
1915.....	74%	77.1%L	75.4%	+19.5%

*Des Moines station only.

It will be noted from this table that the humidity factor is much more constant than that of rainfall. In all of the months in all three years the humidity runs abnormally high, even in the months in which the rainfall was deficient.

The conditions with regard to humidity are more clearly

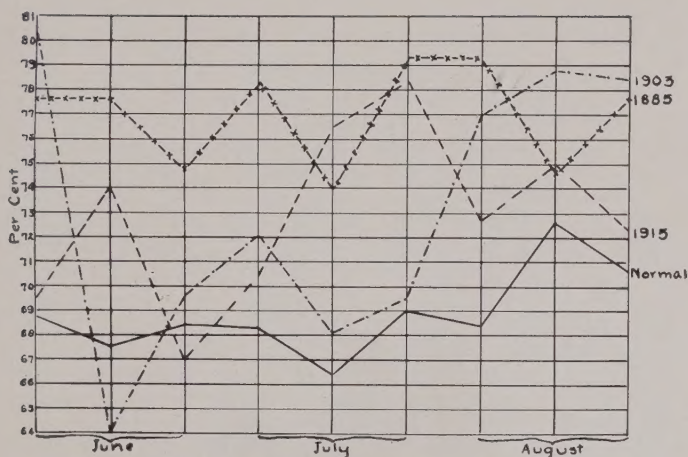


Fig. 2. Per cent of humidity by decades of each month, at Des Moines station.

brought out in relation to the different stages of the development of the disease when presented by decades in fig. 2.

These field data for Iowa conditions are supplied.

Without reviewing the decades of each month in detail, special attention is called to the high degree of humidity for the third decade of July in 1885 and 1915. For the year 1903 this high stage of humidity came a little later and was reached during the first decade of August.

TEMPERATURE.

Probably but few parasitic fungi are more sensitive to temperature conditions than late blight. Its occurrence in Iowa is dependent upon comparatively cool weather, and in the cool climate of Maine upon comparatively warm weather. In both instances the mean temperature for the years of its recurrence is probably much the same. In the one territory its growth is limited by too low a normal and in the other by one too high.

The mean temperature in Iowa by months is given in the table on the next page:

Taken as a whole, the years of outbreaks were distinctly cool seasons. Subnormal temperatures were very pronounced for the summers of 1903 and 1915. The same is true for 1885 with the exception of the third decade of July. During this decade the humidity however was above normal giving one of the highest readings on record. (Fig. 3).

*The climatological data of this bulletin are based upon the records of the Iowa Weather Bureau. Thanks are due the director, G. M. Chappel. The means given in the temperature table above are based upon 1915 normal, hence the apparent discrepancy with the above figures.

MEAN TEMPERATURES FOR IOWA IN THE YEARS OF POTATO BLIGHT OUTBREAK

(Fahrenheit)

	June	July	August	Total departure	Total departure. percentage
Normal	69.1°	74.1°	71.8°		
1885	69.0°	75.9°	68.7°	— 1.4°	— .65%
1903	64.6°	70.9°	69.1°	—10.4°	—4.79%
1915	65.1°	69.5°	65.9°	—14.6°	—6.83%

1885. The temperature was .1° below normal for June and 3.1° deficient for August. July averaged 1.8° above normal.

1903. June—"The month just closed was the coldest June on record for the period of 14* years." The daily mean was 5.6° below normal. July—Daily mean 1.6° below normal. August—3.1° below normal. "There have been two colder Augusts in the past thirteen years. 1890 and 1897."

1915. June—4° below normal. "The coldest June since 1903. At numerous stations the monthly mean and absolute maximum temperature for the month was lower than ever before recorded in June." July—"With one exception the coldest July of record." "August, 1915, was the coldest month of that name in the climatological history of the state. The monthly mean temperature and the monthly extremes were all lower than was ever before recorded and the daily means were below the normal means on all but four or five days during the month." Frost occurred in some parts of Iowa in every month of the year 1915.

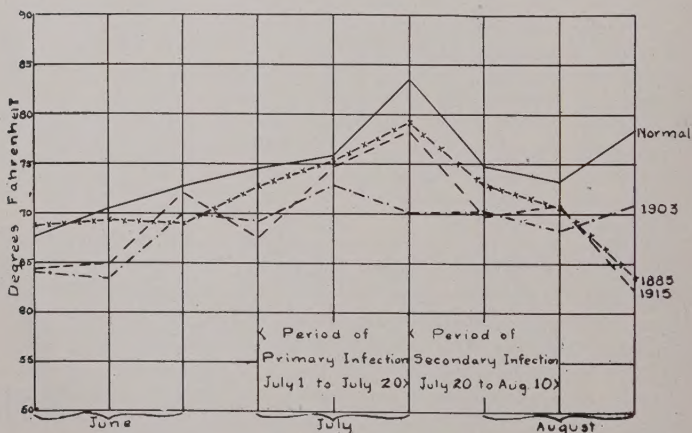


Fig. 3. Mean temperature by decades of each month at Des Moines station.

The deduction is clear that the normal mean temperatures for the summer months are too high for the development of late blight in Iowa and are limiting factors.

The exact degree between the upper and lower temperatures at which this disease thrives under field conditions is difficult to determine. Selby ⁴ in laboratory tests found that temperatures ranging from 65° Fahrenheit to 75° Fahrenheit produced favorable conditions for the disease and Galloway states that "A normal temperature of from 72° Fahrenheit to 74° Fahrenheit accompanied for any considerable time by moist weather furnishes the best conditions for the spread of the disease".

Since the normal mean in Iowa for July is 74.1° Fahrenheit and for August 71.8° Fahrenheit, and as the disease has occurred here only in the seasons of subnormal temperature during these months, it would seem that the above figures are perhaps high.

The average of the means for July and August for the three years in question is 70° Fahrenheit. This temperature would seem to represent the danger line. So far as the temperature conditions are a factor, a mean below 70° Fahrenheit for the latter part of July and early August provides favorable conditions for an outbreak of late blight. In this connection it is interesting to note the statement made by Smith ⁵ that "The Critical districts (or late blight) would be along the line of 70° Fahrenheit".

Since the disease is always more or less present through the introduction of infected seed, there is always the probability of an outbreak at a mean temperature below 70° Fahrenheit provided the humidity factor is also favorable.

SOIL TEMPERATURES.

The initial growth of the mycelium in an infected tuber is probably largely a matter of temperature conditions as moisture is supplied directly by the tuber.

The soil temperatures for the season of 1915 in comparison with those for 1914 are presented in the chart in fig. 4.

OUTBREAK.

These readings were taken in the experiment station potato field at a depth of six inches, which probably represents the main zone of tuber development for the potato. It will be noted that soil temperatures for 1915 are strikingly low as compared with 1914. It is to be regretted that this comparison cannot be made with a normal established over a long period of

⁴ Selby, A. D., Ohio Naturalist, Feb. 1907.

⁵ Smith, J. W., Monthly Weather Review. 43:5,234. May 1915.

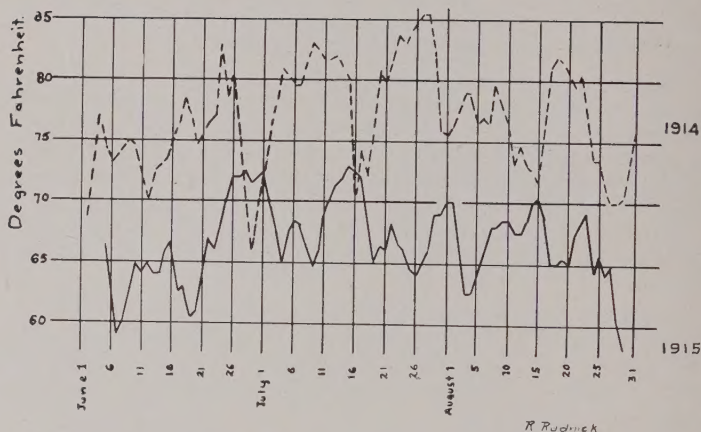


Fig. 4. Mean soil temperatures at Ames, reading taken at a depth of 6 inches.

years. Orton ⁶ reports that in the outbreak of 1893 in Pennsylvania, the soil temperatures for the summer were notably low.

Thru the courtesy of J. G. Mosier of the Illinois Agricultural Experiment station we have the soil temperature records for the year 1915 in comparison with a normal, covering a ten year period at that station.

SOIL TEMPERATURES AT A DEPTH OF THREE INCHES, CHAMPAIGN, ILLINOIS.

1915.	Actual	Normal..	Degree Departure	Percentage Departure
June	71.13	72.0°	—4.57°	—6.03%
July	74.06°	75.8°	— .74°	— .98%
August	70.23°	75.8°	— .87°	—1.21%

In the sunshine chart in fig. 5 is shown the percentage of possible amount of sunshine for the years 1903 and 1915 as compared with the normal.

Particular attention is called to the period covering the third decade of July and the first decade of August of this table in its relation to the period of secondary infection.

Unfortunately the sunshine records for 1885 are not available as they were not taken in this form by the weather bureau at that time.

[6] Orton, C. R. Phytopathology, 1916.

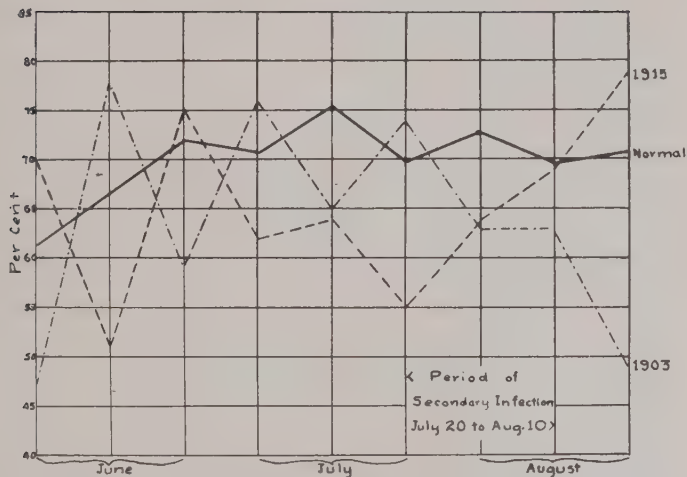


Fig. 5. Per cent of sunshine by decades of each month at Des Moines station.

As expressed in terms of clear, partly cloudy and cloudy days, the record for 1885 was as follows:

	Clear	Partly Cloudy	Cloudy..
June	4	21	5
July	5	15	11
August	11	11	9

The germicidal properties of sunshine are well known. The delicate, thin-walled cells of the summer spores are quickly destroyed by exposure to bright sunshine. The predominance of cloudy days was, therefore, an important aid in the propagation of the disease.

DISEASE RESISTANT VARIETIES

In the outbreak of 1915, particular note was taken as to any differences in the degree of susceptibility among the varieties grown in Iowa. The station collection for that year contained the following varieties, which may be taken as representing the leading commercial sorts grown in the cornbelt, Early Ohio, Irish Cobbler, Rural New York and Pearl. All of these were seriously affected by the disease and there was no appreciable difference in the degree of injury.

An occasional hill within the same variety remained healthy

thruout the season, giving evidence of a greater degree of immunity and suggesting the possibility of the value of hill selection for disease resistance in regions where the disease is of more frequent occurrence.

Melhus found the following varieties to be particularly resistant to late blight: Garnet Chile, Spaulding's Rose No. 4, Dakota Red, Cambridge Russet, and Jersey Peach Blow.

These are all of the redskinned Bliss's Triumph type. From the market standpoint a whiteskinned potato is given a decided preference. This doubtless explains in some measure why these varieties are not more widely grown commercially as some of them were introduced by Chauncey Goodrich more than half a century ago.

The securing of a *Phytophthora*, resistant variety and also one which combines the necessary commercial qualities is still an unsolved problem. Stuart ⁷ found some of the foreign sorts to be more immune than the American varieties. These foreign types, however, are inferior in other respects to our native kinds.

Judging by what has actually been accomplished along the line of disease resistant strains with cotton and with other plants, there is every reason to believe that there are also excellent possibilities in the case of the potato. This will require, however, systematic efforts and a considerable period of time for its accomplishment.

SEED INFECTION.

The advice has been repeatedly given in print regarding the necessity of using clean seed as a means of holding this disease in check.

On the farm of J. P. Dawson at Aurelia, Iowa, the Iowa Agricultural Experiment Station has been conducting cooperative potato experiments for a number of years past. The variety used in the year of 1915 was chiefly Rural New Yorker, the stock of which has been grown continuously by Mr. Dawson for 27 years. Since the last outbreak occurred in 1903, the seed has been free from infection for the last 12 years. In the same field were plots of "certified seed" of the Pearl and Early Ohio from Wisconsin, and the Burbank, Irish Cobbler and Rural New Yorker from the Red River Valley of Minnesota.

The plants from native seed were the first to be attacked by the blight, there being a difference of from five to seven days in favor of the northern grown stock, due probably to a greater degree of vigor of the northern grown seed. Care was exercised in the purchase of the foreign seed and it was

(7) Stuart, Wm. Bull. Vt. Exp. St. 115. May 1905.

also examined in cutting. In this instance the entire planting was free from blight and the infection was brought in from adjoining fields. The disease spreads at an incredible rate and may propagate upon other plants of the potato family. There was very general complaint regarding the defoliation of tomato plants in 1915, due probably to this same disease.

The conclusion seems inevitable that the grower cannot protect himself from this disease by using clean seed. The majority of growers in the cornbelt restock with northern grown seed every three or four years. This means that infected seed is being continuously introduced and the disease is so infectious in character that under favorable climatic conditions it spreads at an incredible rate to all parts of the state.

HOME GROWN VS. IMPORTED SEED.

Many growers are at this time raising the question as to the advisability of purchasing new seed in view of last year's outbreak. This idea is based upon the erroneous assumption that the northern grown seed is free from infection. In normal seasons the conditions are likely to be just the reverse. Furthermore, since this disease was practically universal throughout the potato belt, the only possible source of clean seed would be the arid regions of the west. Generally speaking stock from that section is not satisfactory for planting in the rainbelt. It is therefore evident that the grower will gain nothing by purchasing new stock particularly at the present high prices so long as his present supply is satisfactory in other respects.

In this connection attention is called to the fact that since the disease carries over only in the potato tuber, the suggestion as to danger from planting on infected soils is groundless. The burning of the tops is also useless for the same reason.

While clean seed is not effective as a means of guarding against loss, there is an important reason for not using infected seed and that is on account of its low germinating quality. The temperature and moisture conditions suitable for the development of the shoot are also ideal for the initial growth so that the mycelium grows through the eye and up the shoot so that the mycelium grows through the eye and up the young shoots. Many of the eyes are seriously injured by the growth of the mycelium, consequently they form a weak growth or fail entirely. At a high soil temperature the mycelium develops much faster than the shoot, hence under these conditions the seed piece fails entirely.

Twenty-four medium sized tubers of the Early Ohio were planted in a bench in one of the cool houses at the college on

January 1, 1916. At the end of six weeks, only two of them showed vigorous sprouts. Of the remaining tubers, two threw up very weak sprouts and twenty of them rotted entirely. One of the tubers developed a blight infected shoot thus corroborating the conclusions of Melhus. Two months after planting this shoot was scarcely one-third the height of the others and showed clearly by its arrested development the effects of the fungus. The use of the diseased tubers means a low stand and a reduced yield. Affected tubers may be detected at cutting time by the shrunken areas on the surface and brownish discoloration of the flesh. In its more advanced stages the tubers are totally over run with the dry rot which of course is readily recognized. It is a good practice to notice the color of the flesh carefully in cutting and throw out everything that shows any evidence of discoloration. The off color may not always be due to this particular disease but in any case the grower will profit by the practice.

STORAGE QUALITY OF BLIGHT INFECTED POTATOES

The development of dry rot, which represents the advanced stage of the late blight disease in the tuber, is often the cause of a serious loss of potatoes in storage. Blight infected crops have the general reputation of being poor in keeping quality and the dealers are particularly cautious about stocking up in the years of its occurrence.

The way in which this condition affects the grower is strikingly illustrated by the 1915 crop. The yield in the majority of the commercial sections of the state was reduced from one-third to one-half by this outbreak. This was evidenced, not only by the actual returns at harvest time, but also by the fact that the supply on hand January 1, 1916, was 38 per cent less than one year ago ⁹. Despite this shortage, prices were only average for a good part of the harvest season and there was a general hesitancy about stocking up for fear of heavy losses from shrinkage. By the middle of January, however, when most of the stock was out of the hands of the grower, the retail price reached as high as \$1.65 per bushel. The prejudice against handling blighted stock was also indicated by the preference shown Dakota stock and resulted in its commanding a premium of from ten to fifteen cents per bushel over Iowa grown.

The problem of handling a blighted crop is therefore an important one from the standpoint of both the producer and consumer. Studies made by Melhus ¹⁰ and others indicated that this organism becomes inactive below 40° Fahrenheit. This

(9) Monthly Crop Reporter, U. S. Dept. Agr. 2:1-8, Jan. 1916.

(10) Melhus I. E. Res. Bull. U. S. A. Agr. Sta. 37.1915,

being true, it should be possible to arrest the growth of the mycelium and prevent loss by dry rot if the potatoes are held at a uniform temperature below 40° Farenheit.

To determine the storage quality of a crop held under these conditions, 600 bushels of Rural New Yorkers were placed in natural storage. These were grown upon the farm of W. P. Dawson, previously referred to, and were from a field planted about the middle of May. The soil is a loess formation and was in alfalfa the previous year. The yield in this field averaged approximately seventy bushels per acre, which is about one-half the average yield on this farm in an alfalfa and corn rotation.

The shrinkage in grading was heavy being over sixteen per cent on a one and six-eighths screen and the average of the tubers was somewhat undersize due to their arrested development from the disease. The stock showed very little evidence of soft rot, a bacterial infection which is often associated with

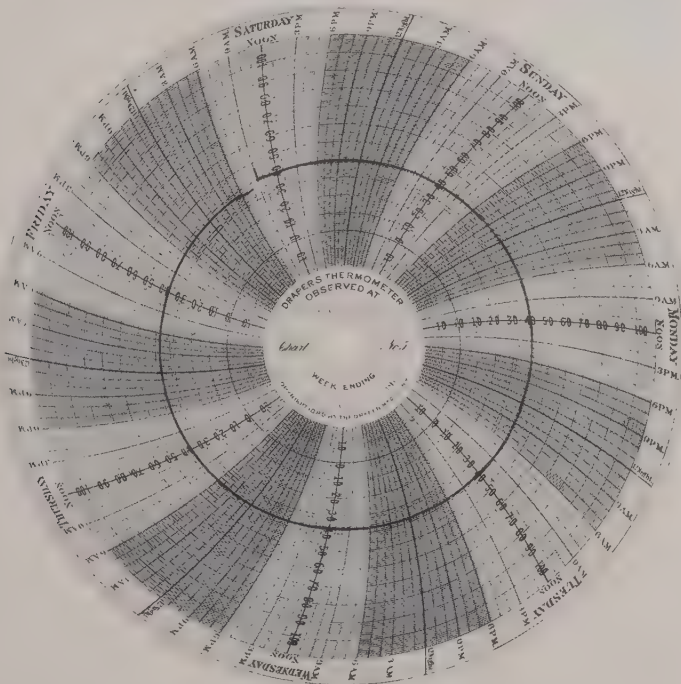


Fig. 6. Chart showing temperature of potato cellar.

late blight and which may cause an even more serious loss, either in the ground or in storage if the temperature is high. The stock was placed in storage November 18, 1915. As indicated by the thermometer record for the week of December 11 (in fig. 6) the temperatures were very uniform from week to week, the average being 38° Fahrenheit.

On January 1, 1916, a tuber count was made by the writer in company with Dr. Melhus for dry rot infection. Less than two per cent of the tubers showed any indication of dry rot at this time and on many of these it was only a trace so that they were still usable as table stock.

On March 1, 50 bushels of this same lot were stored in an adjoining room at a temperature of approximately 50° Fahrenheit. Within three weeks the percentage of infection in this lot increased eight per cent. This fact suggests that it is not desirable to take blight infected stock out of storage very far in advance of the time of its consumption. If held at a high temperature for any considerable length of time the disease again becomes active.

Humidity readings taken at intervals ran almost uniformly at 75 per cent, there being less than 1 per cent of variation at any time up to March 1. It should be noted in this connection that at this high degree of humidity, the loss in weight from shrinkage is very low. However, such a high degree of humidity is inadvisable except at low temperature, as a high degree of temperature and high humidity combined form ideal conditions for both dry rot and soft rot, particularly the latter.

Two bushels of Rurals from this same lot were stored in the basement of a residence on October 18. The mean temperature in this room probably ranged between 55° Fahrenheit and 60° Fahrenheit though close records were not kept. They were held at what may be regarded as average storage conditions in a home, having a hot air furnace. The count on this lot made January 1 showed a loss of 45 per cent and in practically all of the tubers the disease was so pronounced as to make them worthless for table purposes. Jones ¹¹ found an important correlation between storage temperature and dry rot. He reports one lot stored at 40° Fahrenheit which showed seventeen per cent while a second held at 55° Fahrenheit gave a count of fifty-three per cent and the third held at 70° Fahrenheit gave 79 per cent dry rot. In this experiment the low temperature lot showed a much higher percentage of loss than in our work. In the Ames experiment, the potatoes were left in the ground as late as possible, the crop being harvested October 25, 1916. This fact coupled with the absence of soft rot was very much in

(11) Jones, L. R., et al Bull. Vt. Exp. St. 168:257.1912.

their favor and should be borne in mind in connection with the low percentage of loss noted above for the storage period.

Thirty-eight degrees Fahrenheit would seem to be the ideal storage temperature for potatoes and one that may be readily supplied by natural storage except in the early autumn. Potatoes may be held in a prime condition at as low a temperature as 32° Fahrenheit, in fact we have found for seed purposes that stock held at this low temperature is usually stronger and more vigorous than the average. Such potatoes, however, are objectionable for culinary use on account of the "sweetish taste" due to the conversion of the starch into sugar. Appleman¹² found that the potato actually freezes at 28° Fahrenheit and that there is a slight formation of sugar even at 38° Fahrenheit. At this latter temperature, however, the quantity of starch converted into sugar must be inappreciable as no complaint was made regarding their flavor at the college cafe where the entire supply of 600 bushels was consumed. Furthermore, potatoes held at a lower temperature than 38° may be restored to their normal flavor by holding them for a few days in a warm room.

The conclusion seems warranted that a blight infected crop may be held in storage at a very slight loss from dry rot provided the dealer or merchant is reasonably equipped with natural storage facilities. The very general complaint regarding their storage quality is clearly due to their being held at too high a temperature. The average grower and dealer is very poorly equipped along the line of storage facilities. Natural storage will fully meet the requirement if properly constructed. Such provisions would result to the advantage of both the producer, dealer, and consumer.

Degree of Injury as Affected by Time of Planting

The late blight makes its appearance in this section the latter part of July or early in August. Usually within seven to ten days following an outbreak, the foliage is entirely destroyed. With the destruction of the foliage, tuber development also ceases. The yield for the season is therefore determined by the advancement the crop has made preceding the outbreak. The correlation between the time of planting and late blight injury is set forth in chart (fig. 7).

These plots contain one-fifth of an acre each and all were planted with the one variety, Rural New Yorker. The average yield for all the plots was distinctly in favor of early planting. Plot 6 is an exception, probably due to the fact that a portion

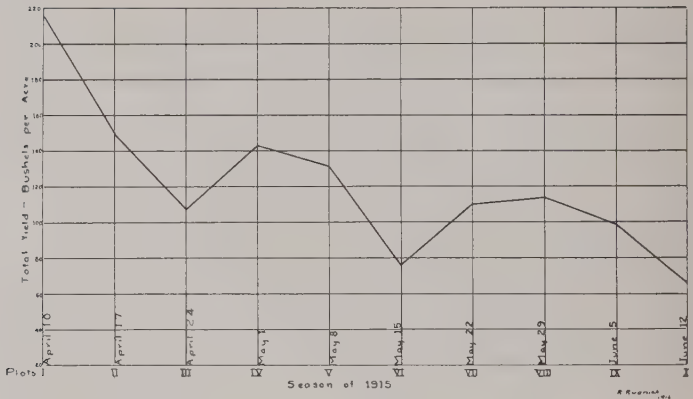


Fig. 7. Injury from late blight as affected by date of planting.

of this area was formerly an old roadbed, hence the soil was not in good condition.

Early planting would therefore seem to be one of the most effective methods of avoiding loss from late blight. However, since this plague is of rare occurrence in Iowa, it is evident that the grower cannot base his normal field practices upon exceptional rather than average conditions.

The Truck Crops section of the Iowa Agricultural Experiment station has had under way for the past five years an experiment to determine the most profitable time of planting potatoes as correlated with soil temperatures and climatic conditions. To date indications point to the conclusion that early potatoes are distinctly favored by early planting.

In the case of late varieties, the yields for three years favor early planting, that is, the early part of April, and for one year, the middle of May. The remaining year 1911 was abnormally dry and the yield on all of the plots was unusually low, the plot planted May 23 being slightly in the lead.

Reliable data covering this question for this section will not be available until the work has been carried over a series of years but the data so far available seem to favor early planting of both early and late varieties under average conditions.

The experiments of Clinton¹³ at the Connecticut Experiment station favor early planting for early varieties but not for late sorts. He reports that the latter "if planted too early, suffer more in years of drouth than if planted later as the less mature stock will revive more vigorously when the rains do come."

(13) Clinton, G. P. Rep. Conn. Exp. St. 10:751.1909.

As judged from the standpoint of moisture supply for this section, it will be noted by table on page 289 that the first decade of August normally is the driest period of the summer. The second decade of August runs higher in moisture than any corresponding period in either July, August, or September. The averages for both July and August are also higher than for September.

Under Iowa conditions, high temperature is probably a more important limiting factor than moisture supply. By referring to the chart on page 292, it will be observed that the highest mean of the summer comes during the third decade of July. The plant passes through its critical stage of development during this period and it is largely a question as to what stage of its development the plant can best endure this hardship. The final yield hinges largely upon the possibility of the tubers developing previous to this period or of the plant retaining sufficient vigor to revive following it. The time the plant is allowed for doing this is also another possible angle as killing frosts normally occur in Central Iowa the last week in September.

KEEPING QUALITY AS AFFECTED BY TIME OF DIGGING

The grower is confronted with two alternatives in handling a blighted crop. He may dig early and market immediately or store, or defer digging as late as possible.

If soft rot which usually accompanies the late blight injury is developing rapidly, the temptation is to unload the crop as soon as possible. The question, however, must be considered from the standpoint of market conditions and storage facilities as well as the loss from rot. As indicated by the accompanying chart (fig. 8), the price of potatoes is highest early in the season and gradually drops until the main harvest season is on, when it remains at a level for a considerable period.

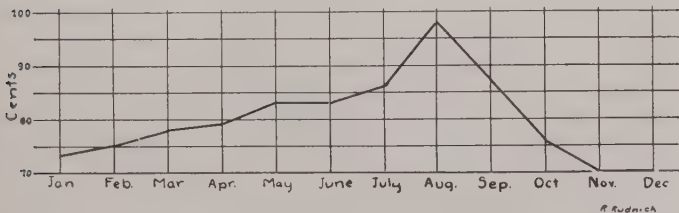


Fig 8. Average price of potatoes per bushel (farm value), 1909 to 1915, inclusive.

Under normal conditions the early market is, therefore, the best one. However, in years of blight, the market is invariably

seriously demoralized through anxiety to unload. Rains are usually frequent, making it difficult to load the cars with bright stock or in a reasonably dry condition. Consequently their wet condition combined with high temperature, causes soft rot to develop very rapidly resulting in cars arriving in bad condition and many of them being rejected. Usually the shipping conditions are greatly improved with cooler weather.

A local market shipped only up to the point that it can clean up is the ideal proposition. In this case the grower can begin to market early and distribute the work of harvesting over a wider period. Under these conditions the grower can well afford to contract at a flat price for the season below the current price but above the probable winter price and thus begin to move his stock at once.

The question of early digging for storage is primarily one of temperature conditions. If the storage cellar temperature is higher than that of the soil, evidently the loss from decay will be correspondingly greater by digging and delayed harvesting would be advisable.

Our own temperature records for the past season indicate that the soil cools out faster than the storage cellar and from observations made over the state, we believe this to be a general condition. This was in part due to the fact that the circulation of air in the storage room was sluggish hence the full benefit of the cool night temperatures was not secured. For the week ending September 6 for example, the cellar temperature was 70° Fahrenheit while the mean minimum outside was 53° Fahrenheit. The mean soil temperature at a depth of six inches for the same period was 65° Fahrenheit. The cellar is of the conventional type with a cold air intake at the bottom at one end and a warm air outlet at the top at the opposite end. It is believed that this plan could be materially improved upon from the standpoint of air circulation.

Studies at the Maine Experiment station 14 favor delayed digging. One lot harvested September 8 showed an average loss of 55 per cent by January 1. The second lot dug October 7 gave a loss of 11 per cent by January 1. In this experiment, neither the soil nor storage temperatures are given.

The danger from frost injury is another possible angle to the situation. Late blight occurs in cool seasons and in these years killing frosts come unusually early. In 1915 for example heavy frosts occurred in many localities on September 15 and were quite general on September 21, which was ten days in advance of the normal.

SPRAYING FOR THE CONTROL OF LATE BLIGHT.

Since late blight is of rare occurrence in Iowa, spray applications for its control would not be profitable as a regular field practice. In view of its being thoroughly established throughout the state at this time, spraying may prove advantageous, particularly if the season is favorable to its development. Experiments at New York and other stations prove conclusively that the disease can be effectively and profitably controlled with the bordeaux mixture. From five to seven applications are required. They may be combined with an insecticide spray. *

*For full information regarding spray mixtures and the time of their application, apply to the Bulletin Editor for the spray bulletin (Extension No. 35.)

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